UNITED STATES PATENT APPLICATION FOR:

PLATEN WITH PATTERNED SURFACE FOR CHEMICAL MECHANICAL POLISHING

INVENTORS:

GOPALAKRISHNA B. PRABHU
ERIK S. RONDUM
PETER MCREYNOLDS
THOMAS OSTERHELD
GARLEN C. LEUNG
JACK ARLUCK
ADAM H. ZHONG
GREGORY E. MENK

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Emma Koh
Signature

EMMA KOH
Name

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MOSER, PATTERSON & SHERIDAN, LLP
3040 Post Oak Boulevard
Suite 1500
Houston, TX 77056

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending United States Patent Application Serial No.10/619,745, filed July 15, 2003, which is a continuation of United States Patent No. 6,592,438, issued July 15, 2003, which is a continuation of United States Patent No. 6,220,942, issued April 24, 2001, all of which are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to an apparatus for polishing substrates. More particularly, the invention relates to a patterned platen for supporting a polishing material for chemical mechanical polishing of substrates.

Background of the Related Art

[0003] In the fabrication of integrated circuits and other electronic devices, multiple layers of conducting, semiconducting and dielectric materials are deposited and removed from a substrate during the fabrication process. Often it is necessary to polish a surface of a substrate to remove material to facilitate the formation of metal interconnects between devices formed on the substrate. The polishing process is often referred to as chemical mechanical polishing (CMP).

[0004] Typically, the polishing process involves the introduction of a chemical slurry during the polishing process to facilitate higher removal rates and selectivity between films on the substrate surface. In general, the polishing process involves moving a substrate while in contact with a polishing material while under controlled pressure and velocity in the presence of a polishing fluid.

[0005] An important goal of CMP is achieving uniform planarity of the substrate surface. Uniform planarity includes the uniform removal of material deposited on the surface of substrates as well as removing non-uniform layers which have been deposited on the substrate. In many applications, the polishing pressure applied to the substrate (i.e., the force of the substrate against the polishing surface) is often higher near the center of the substrate, resulting in the center of the substrate polishing faster than the perimeter of the substrate. In order to achieve good processing results, the tendency of the substrate to polish faster at its center must be compensated. In other applications, it may be desirable to polishing one region of a substrate at a rate different than another region of the substrate. Additionally, it would be desirable if the measures taken to compensate for the disparity in polishing rate across the substrate would be part of the polishing system hardware, thereby minimizing process drift and enhancing batch to batch uniformity.

[0006] Therefore, there is a need for a platen that enhances polishing performance.

SUMMARY OF THE INVENTION

[0007] A platen having a patterned upper surface for supporting a polishing material in a chemical mechanical polishing system is provided. In one embodiment, a platen for supporting a polishing material in a chemical mechanical polishing system includes a body adapted to support a polishing material during processing and having a substantially rigid non-planar upper support surface for supporting the polishing material during polishing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be

considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] Figure 1 is a simplified perspective view of a chemical mechanical polishing system;

[0010] Figure 2 is a schematic side view of one embodiment of a polishing station;

[0011] Figures 3-6 are a schematic view of various embodiments of a polishing station; and

[0012] Figure 7 is a top view of the platen of Figure 6.

[0013] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

[0014] The present invention generally relates to a platen having a patterned surface for mounting a pad, such as a polishing pad or web of polishing material, thereto. The patterned surface is non-planar, resulting in greater polishing pressure over predefined portions of the patterned surface during processing, thereby providing control over the profile of material removal from the substrate.

[0015] Figure 1 is a schematic view of a chemical mechanical polishing system 30 having a patterned platen 41. Two polishing systems suitable for chemical mechanical polishing are the MIRRA® and REFLEXION® polishing systems available from Applied Materials, Inc., located in Santa Clara, California. Similar systems are shown and described in United States Patent Nos. 5,738,574, issued April 14, 1998, and 6,244,935, issued June 12, 2001, and are hereby incorporated herein by reference in their entireties.

[0016] In the embodiment depicted in Figure 1, the system 30 has three polishing stations 32 (two are shown) and a loading station 34 disposed on a base 10. A carousel 37 is coupled to the base 10 and supports a plurality of polishing heads 36 rotationally disposed above the polishing stations 32 and the loading station 34. A front-end substrate transfer region 38 is disposed

adjacent to the CMP system and typically includes a substrate cleaner and may optionally include metrology equipment.

[0017] Typically, a first substrate is loaded into one of the polishing heads 36 at the loading station 34 and is then sequentially processed at each of the three polishing stations 32. As the first substrate leaves the loading station for processing, a second substrate is loaded into the next polishing head so that each polishing station 32 is engaged with a substrate simultaneously. At the end of the cycle the substrate is transferred from the polishing head 36 to the transfer station 34. The substrate is then returned to the front-end substrate transfer region 38 and another substrate is placed into the loading station 34 for processing by a robot 20.

[0018] Figure 2 is a schematic view of one embodiment of the polishing station 32 showing the platen 41 and polishing head 36. The polishing head 36 retains a substrate 42 during polishing. The polishing head 36 may comprise a vacuum-type mechanism to chuck the substrate 42 against the polishing head 36. During operation, the vacuum chuck generates a negative vacuum force behind the surface of the substrate 42 to attract and hold the substrate 42. The polishing head 36 typically includes a pocket (not shown) in which the substrate 42 is supported, at least initially, under vacuum. Once the substrate 42 is secured in the pocket and positioned against the polishing material 44, the vacuum can be removed. The polishing head 36 then applies a controlled pressure behind the substrate, indicated by the arrow 48, to the backside of the substrate 42 urging the substrate 42 against the polishing material 44 to facilitate polishing of the substrate surface. The polishing head displacement mechanism 16 rotates the polishing head 36 and the substrate 42 at a velocity V_s in a clockwise or counterclockwise direction. The polishing head displacement mechanism 16 may additionally sweep the polishing head 36 laterally across the polishing material 44 disposed on the platen 41 as indicated by arrows 50 and 52. One polishing head suitable for use with the invention is a TITAN HEAD™ wafer carrier, also available from Applied Materials, Inc. Another suitable polishing head is described in United Sates Patent No. 6,183,354, issued February 6, 2001, and is hereby incorporated by reference in its entirety.

[0019] The polishing station 32 also includes a chemical supply system 54 for introducing a polishing fluid of a desired composition to the polishing material 44. In one embodiment, the polishing fluid may include slurry of alumina or silica particles. The slurry provides an abrasive material which facilitates the polishing of the substrate surface. During operation, the chemical supply system 54 introduces the polishing fluid as indicated by arrow 56 on the polishing material 44 at a selected rate. Alternatively, the polishing fluid may be supplied to the upper surface of the polishing material 44 from a alternative chemical supply source 71 though a port 70 formed in the platen 41. The polishing material 44 disposed on the platen 41 may includes holes 72 formed therethrough to allow polishing fluid to flow out of the port 70 and through the polishing material 44 and into contact with the substrate 42.

[0020] The polishing station 32 includes a polishing material 44 secured to an upper patterned surface 14 of the platen 41. The polishing material 44 may be any polishing material suitable for chemical mechanical processing, such as commercially available polyurethane pads 59 as depicted in Figure 2 or a web 60 of fixed abrasive polishing material as depicted in the polishing station 32A shown in Figure 3. Optionally, a subpad 18 may be disposed between the platen 41 and polishing material 44 to tailor the compliance of the polishing material 44 and the polishing results. It is contemplated that the subpad 18 may be utilized in any of the embodiments described herein.

[0021] The polishing material 44 is retained to the upper surface 14 of the platen 41. In the embodiment depicted in Figure 2, the polishing material 44 is held by vacuum to the platen 41. A port 68 is formed through the upper surface 14 and coupled to a vacuum source 69 so that a vacuum may be drawn between the polishing material 44 and platen 41.

[0022] Alternatively, in embodiments where a magnetic layer 65, such as a sheet of metal, disposed, is coupled to or embedded in the polishing material 44, the polishing material 44 may be magnetically coupled to the platen 41. For example, the platen 41 may include a magnetic device 66, such as a permanent magnet or an electromagnet powered by a power source 67, that attracts and secures the polishing material 44 to the platen 41.

[0023] The platen 41 is coupled to a motor 46 disposed below the base 10 or other suitable drive mechanism to impart rotational movement to the platen 41. During operation, the platen 41 is rotated at a velocity V_p about a center axis X such that the polishing material 44 and a substrate 42 retained by the polishing head 36 (shown in an elevated position) are moved relative each other while in contact therebetween. The platen 41 may be rotated in either a clockwise or counterclockwise direction, and in one embodiment, is rotated in the same direction as the polishing head 36. It is contemplated that other relative motion between the polishing material 44 and the substrate 42 retained by the polishing head 36 may be utilized, including, but not limited to linear and/or orbital motion, among others. It is also contemplated that one of the platen 41 or polishing head 36 motion within the plane of the polishing material 44 may be fixed.

[0024] To enhance control of the polishing profile of the substrate 42, the upper patterned surface 14 has a non-planar configuration. The non-planar configuration of the upper patterned surface 14 positions the overlying polishing material 44 at a various elevations relative to the substantially planar orientation of the substrate 42 retained in the polishing head 36. A reference line 24 that is perpendicular to the axis X is provided to illustrate the non-planarity of the upper surface 14. As the polishing head 36 is lowered to contact the substrate 42 with the polishing material 44, the difference in elevation across the upper patterned surface 14 (which are exaggerated for purposes of illustration) results in areas of more polishing force 48 near the high portions of the upper surface 14. Since the upper surface 14 of the platen 41 is substantially rigid, the non-planar orientation of the upper surface 14 is maintained after multiple polishes, thereby contributing to enhanced substrate to substrate repeatability and predictable polishing results. The patterned differences in elevations fabricated into the hard platen top surface is somewhat converted by the flexible, compressible polishing material 44 disposed on top of the platen to a same pattern of differences of pressures asserted between the substrate and polishing material during polishing that is more the direct effect affecting the desired process of non-uniform material removal from the substrate. In one embodiment of the invention utilizing a web of polishing material such as

depicted in Figure 3, the upper surface 14 of the platen 41 may have at least one change in elevation (and/or relief) in range between about 2 to about 24 mils.

[0025] In the embodiment depicted in Figure 2, the upper surface 14 is convex resulting in portions of the substrate contacting the polishing material 44 closer to the center axis X having a greater polishing force 48, thereby locally increasing the rate of polish. As the motion of the substrate relative to the polishing material 44 may be set in a predefined polishing routine, the polishing profile of the substrate may be controlled by pre-determining which portions of the substrate 42 are in contact with higher elevations of the upper patterned surface 14 during a specific polishing routine.

[0026] It is contemplated that other configurations of the patterned upper surface 14 may be utilized to produce different polishing results. For example, in the embodiment of a polishing station 32B depicted in Figure 4, an upper patterned surface 14A of the platen 41 is concave.

[0027] Figure 5 depicts another embodiment of a polishing station 32C. The polishing station 32C includes a platen 41 comprised of a substantially rigid material, such as aluminum or polyetheretherketone, among others. The platen 41 has an upper patterned surface 14B that has a plurality of high and low portions that support the polishing material 44. In one embodiment, at least one of a high and low portion of the upper patterned surface 14B of the platen 41 is located in a working area 80. The working area 80 of the upper patterned surface 14B is defined as the portion of the upper patterned surface 14B upon with the substrate 42 is disposed during processing. The working area 80 may be large or small; for example, the working area 80 may be smaller than the diameter of the substrate (on small pad systems, not shown), or may be greater than or equal to the diameter of the substrate (up to the entire pad diameter).

[0028] In the embodiment depicted in Figure 5, the working area 80 includes an inner working area 82 and an annular outer working area 81. The transition between the inner working area 82 and the outer working area 81 may be smooth, defining an undulating or wavy upper surface 14. The inner working area 82 is configured to be recessed relative to the outer working area 81. As the center of the substrate 42 is in contact during processing with a

portion of the polishing material 44 positioned over the inner working area 82 for a longer period than that portion of the polishing material 44 disposed over the outer working area 81, the perimeter of the substrate 42 experiences more polishing force 48 during processing than the center of the substrate, resulting in a faster polish at the perimeter of the substrate. The relative difference in elevation between the outer and inner working areas 82, 81 may be tailored to compensate of other processing parameters that would cause faster polishing rates in the reverse orientation, thereby resulting in a planar, polished surface of the substrate 42. It is contemplated that the working area 80 may be divided into multiple (i.e., more than two) regions of high and low areas, and that the areas may be configured in geometries other an annular, such as, for example, a plurality of mounds, ridges, bumps, or grids.

[0029] Figure 6 shows a side view of another embodiment of a polishing station 32D. The platen 41 of the polishing station 32D includes a patterned upper surface 14C whereon the polishing material 44 may be disposed. Generally, the patterned upper surface 14C has features formed therein defining a raised area and a recessed area. In the embodiment shown in Figure 6, the raised area consists of a plurality of protrusions 60 while the recessed area is a plurality of intersecting grooves 62 defined by the protrusions 60. The height of the individual protrusion 60 is selected such that the upper surface 14C is non-planar. More specifically, the recessed area consists of two parallel sets of equally spaced orthogonally intersecting grooves 62 in a checkerboard pattern. Each groove 62 traverses the upper surface 14C of the platen 41 from one perimeter to the another. Thus, the grooves 62 are not contained, or blocked, at either end. However, the present invention also contemplates an embodiment having blocked grooves.

[0030] The protrusions 60 cooperate to provide a substantially non-planar mounting surface 64 along a common surface defining the upper surface 14C for supporting a polishing material 44 as shown in Figures 6-7. The polishing material 44 may be attached using a commercially available pressure sensitive adhesive (PSA). In this embodiment, the present invention eliminates the need for a subpad by controlling the ratio between raised and recessed area to control polishing material compliance. The protrusions 60 ensure sufficient

rigidity (or stiffness) while the grooves 62 allow the proper proportion of pad compliance to accommodate a substrate's varying topography.

[0031] The dimensions of the patterned surface may be varied to achieve the desired proportions of compliance and rigidity. In general, the mounting surface 64 makes up to between about 20 to 95 percent of the total upper surface area but may be varied according to the pad thickness and modulus, as well as the applied polishing pressure. In a specific embodiment shown in Figures 6-7, where the platen 41 diameter is about twenty (20) inches, the groove depth is about 0.250 inches and the groove width is about 0.062 inches. Thus, the total surface area of the mounting area 64 is about 20-95 percent of the total area of the platen 41. The diameter of the platen 41 may be varied to accommodate any substrate size such as 100mm, 200mm or 300mm substrates. As a result, relative sizes of the grooves and protrusions will vary accordingly.

[0032] It is to be understood that the present invention allows for virtually limitless design variations. Figures 6-7 show only one possible embodiment according to the invention. In another embodiment, the raised area and recessed areas of the platen 41 may be defined by intersected radial grooves. The embodiments described above are merely illustrative and a person skilled in the art will recognize other embodiments within the scope of the present invention.

[0033] While foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.